Project Report: Evolution of Atmospheric O_2, Climate, and Biosphere − Lee Kump

Lead Team:	***Pennsylvania State University***
Project Title:	***Evolution of Atmospheric O_2, Climate, and Biosphere − Lee Kump***
Project Investigator:	***Lee Kump***

Project Progress

My group has primarily focused on the problem of environmental evolution during the Archean−Proterozoic boundary, with the major contribution being the article in *Geochemistry Geophysis Geosystems* in 2001. This article generated considerable interest among people interested in mantle evolution (see Sleep's *Nature News and Views* article) as well as in the evolution of the atmospheric composition.

Ellen Herman (MS Student) has received some support from the Pennsylvania State Astrobiology Research Center (PSARC) to develop a numerical model of the microbial mat. The model is used to evaluate how microbial mats may have differed during Archean and Proterozoic times, when the overlying water may have been O_2 poor and/or sulfide rich. Her thesis is now completed and will be published soon.

Andy Kurtz's (postdoc) work on Ge/Si ratios in Precambrian cherts is being written up presently. The goal of this research was to determine the intensity of chemical weathering through geologic time and the relative influences of riverine and hydrothermal sources of Ge (and by proxy, Si) in the Precambrian.

I have collaborated with my Task 5 colleagues on the Snowball Earth problem. Modeling of the paleoceanography of the Neoproterozoic is under way. I have also collaborated with Bill Seyfried (U. Minn.) on the response of seafloor hydrothermal systems to depressurization during sea−level lowstands. That work is under revision for *Nature*.

We have done a bit of fieldwork. I participated in the first Western Australia field trip and collected samples through the Paleoproterozoic diamictite (Snowball Earth 1) interval. Jay Kaufman (U. Md.) is in possession of those samples, and will be running C−isotope analyses shortly. Mike Moreland, Master's student, and I have collected samples from Green Lake, NY,

anticipating that this could be a site for intensive study as an analog for Precambrian planktonic ecosystems.

Finally, in collaboration with colleagues from a variety of institutions, we have published a paper on CO_2 levels just following the Cretaceous Tertiary mass extinction (Beerling et al., 2002, PNAS 99, 7844−7847) based on modeling (my part) and fossil leaf stomatal density.

Highlights

- Carbon dioxide levels rose to >2300 ppm within 10,000 years of the Cretaceous−Tertiary extinction event. This almost certainly requires an impact into a limestone target, as proposed for the Chicxulub structure (Beerling et al., 2002 PNAS 99, 7844−7847)

- Deep mantle plumes may have carried more oxidized mantle to the surface at the end of the Archean (2.5 billion years ago), reducing the volcanic sink for photosynthetic oxygen and thus promoting the establishment of an oxygen−rich atmosphere.

- Oxygen levels in Archean cyanobacterial mats may have exceeded modern atmospheric saturation values by a factor of 2−3, as modern mats do during afternoon hours, based on modeling experiments performed at Penn State. This conclusion is independent of the oxygen or sulfide content of the overlying water.

Roadmap Objectives

- ***Objective No. 5:*** Linking Planetary Biological Evolution
- ***Objective No. 6:*** Microbial Ecology
- ***Objective No. 12:*** Effects of Climate Geology on Habitability
- ***Objective No. 14:*** Ecosystem Response to Rapid Environmental Change

Field Expeditions

Field Trip Name: Initial Reconnaissance of Green Lake, NY State	
Start Date: 01/01/2001	***End Date:*** 01/01/2002
Continent: North America	***Country:*** USA
State/Province: New York	***Nearest City/Town:*** Fayetteville
Latitude:	***Longitude:***
Name of site(cave, mine, e.g.): Fayetteville Green Lake	***Keywords:*** microbial biogeochemistry, sulfur cycle, nitrogen cycle, meromictic lakes, cyanobacteria, sulfur bacteria
Description of Work: Initial reconnaissance of the inorganic chemistry of this meromictic lake, in anticipation of further, intensive work on this	

Archean/Proterozoic planktonic, microbial ecoystem analog. Chris House and Aubrey Zerkle (PSU) have also performed some preliminary genetic analyses of microbial diversity at the lake.

Members Involved: Lee Kump, Mike Moreland